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ERTS Contracting Officer
Code 245, GSFC
Greenbelt, Maryland 20771

Subject: Type II Progress Report No. 2

Period Covered: 1 January 1973 - 30 June 1973

Title: A Scheme for the Uniform Mapping and Monitoring of Earth Resources and Environmental Complexes Using ERTS-1 Imagery

GSFC ID: PR 534
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OBJECTIVES

To develop, test and specify a practical procedure and system for the uniform mapping and monitoring of natural ecosystems and environmental complexes from space-acquired imagery.

With primary emphasis on ERTS-A imagery, but supported by appropriate aircraft photography as necessary, our objective furthermore is to accomplish the following:

1. Develop and test in a few selected areas of the western United States, a standard format for an ecological and land-use legend for making natural resource inventories on a simulated global basis.

2. Based on these same limited geographic areas, identify the potentialities and limitations of the legend concept for the

recognition and annotation of ecological analogs and environmental complexes.

An additional objective is to determine the optimum combination of space photography, aerial photography, ground data, human data analysis and automatic data analysis for estimating crop yield in the rice growing areas of California and Louisiana.

MAJOR ACCOMPLISHMENTS

Rice Analog Studies

Data collecting in the rice growing areas of California and Louisiana has been arranged with cooperating farm advisors and growers by visits to the test sites involved. Aerial photographic flights have been made over the test areas (1) during the pre-planting period, and (2) during the post-emergence period as close to ERTS overpass coverage as practical.

Ground visits have also been made to the test areas to observe crop conditions, take documentary photos, confer with farm advisors and verify certain photo interpretation data.

No significant crop-limiting events have been detected to date in the test areas using ERTS images. Because of the presence of cloud cover over the Louisiana test site at the time of ERTS overpasses on all but the 31 March 1973 and 29 June 1973 tracks, intermediate 1973 data are incomplete. It is possible to see most of the fields flooded as of the 31 March date, but because of unseasonably heavy rains during the later winter and spring months, the field preparation and crop planting was significantly delayed.

Excellent aircraft photography has been obtained of the sites and test plot maps have been prepared from those photos for use by the growers and ground observers in reporting significant crop factors.

For the California rice test site at Davis/Biggs (Northern Great Valley) we have received ERTS coverage taken when fields were flooded, which permits interpretation of the status of rice planting at that date (10 May 1973). We expect to have more favorable photographic weather in the California test area than the Louisiana test area.

It was interesting to observe the pre-planting soil preparation activities in the Northern Great Valley on the 22 April 1973 ERTS coverage followed by the flooded appearance of those same fields 18 days later on 10 May 1973. Band 7 provided the best indication of these conditions with Band 6 being nearly as useful.

Natural Vegetation Analog Studies

1. Ground Truth and Analog Documentation

A ground truth study in the Sierra-Lahontan area was conducted from May 16 to May 20, 1973. Large examples of homogeneous vegetation types were located and documented with ground photographs, located accurately on USGS topographic maps and each type was outlined on various dates of Band 5 ERTS imagery. On June 13 and July 11 large-scale color and color infrared aerial photography was obtained on selected flight lines to aid identification of ERTS images and further document vegetation types and large-scale imagery of the Colorado Plateau area was obtained from July 11 to July 15, 1973. Forest Service personnel in Delta, Colorado and Bureau of Indian Affairs personnel at Ignacio, Colorado were contacted and helped to select large homogeneous vegetation types that represent

important regional types. All of these types were critically examined in the field to accurately locate types analogous to Sierra-Lahontan vegetation studied in May. Ground photographs were obtained of the vegetation, the sites were mapped on topographic sheets and outlined on a 4, 5, 7 color reconstitution of the Grand Junction frame which had been received one week prior to the ground truth mission. With the color product in hand, much more meaningful and detailed vegetation units could be documented on the ground.

The collaborating Colorado government personnel made detailed vegetation and soils maps available to the investigator and agreed to compile phenological notes throughout the 1973 season.

The following list is a selection of analogous vegetation types that have been documented on the ground and on various ERTS images:

TABLE I - NATURAL VEGETATION ANALOGS

Analog Name	Legend Symbol	Presence in Test Sites		Description
		Colorado Plateau	Sierra-Lahontan	
1) *Sarcobatus vermiculatus* (Hook.) Torr.	324	X	X	Dense greasewood stands on heavy saline/alkaline soils. Annual vegetation important in spring. Occurs on depressions and level flood plains.
2) *Sarcobatus vermiculatus* (Hook.) Torr./ *Artemisia tridentata* Nutt.	324	X	X	Occurs on same areas as #1 but soils are less alkaline or alkaline within 1 or 2 inches of the soil surface.
3) *Atriplex nuttallii* Wats./ *A. confertifolia* (Torr. & Frem.) Wats./ *A. obovata* Mog.	324	X	Present, but not yet located.	Saltbush communities on slopes and well-drained benches above streams and washes. Calcareous soils. Stand composition varies from pure *A. nuttallii* to mixtures of all 3 plus *Artemisia spinescens*, *Eurotia* and *Kockia*.
4) *Sarcobatus baileyi* Cov.	324		X	Occurs on benches and terraces above greasewood sites. Occurs variously mixed with *Atriplex confertifolia*, *Artemisia spinescens*, *Eurotia* and other salt desert species.
5) *Oryzopsis hymenoides* (R. & S.) Ricker	414 (Colo. Plat.) 314 (Sierra-Lahontan)	X	X	Indian ricegrass on light sandy soils. Calcareous conditions with large percentage open ground.
6) *Populus* sp.	342	*P. wizlizenii* (Wats.) Sarg.	*P. fremontii* Wats.	Stands of cottonwood trees along permanent streams in alluvial soils.

TABLE I - CONTINUED

Analog Name	Legend Symbol	Presence in Test Sites		Description
		Colorado Plateau	Sierra-Lahontan	
7) Atriplex confertifolia (Torr. & Frem.) Wats./ Artemisia spinescens Eat./ Grayia spinosa (Hook.) Mog.	324		X	Shadscale areas on well-drained, calcareous, rocky soils. May correlate to some degree with #3.
8) Artemisia tridentata Nutt.	325	X	X	Big sagebrush shrub-steppe vegetation occurs in many habitats in both test sites. Neutral to slightly acid. soils that are generally deeper than 16-18".
9) Artemisia tridentata Nutt./ Purshia tridentata (Pursh) DC.	325	X	X	Sagebrush/bitterbrush mixed. Occurs on very slightly acid/near neutral.
10) Artemisia arbuscula Nutt.	325	X	X	Low sagebrush on shallow rocky, well-drained soils.
11) Juniperus occidentalis Hook.	336		X	Western juniper woodlands on rocky ridges, hills and mountain sides west of 120° 40' W. Long. and north of 40° N. Lat.
12) Pinus monophylla Torr. & Frem./ Juniperus osteosperma (Torr.) Little	336		X	Single-leaf pinyon/Utah juniper woodlands from 5000' to 8000' elevation. Poa sandbergii occurs as a dominant understory species. Analogous to #13.

TABLE I - CONTINUED

Analog Name	Legend Symbol	Presence in Test Sites		Description
		Colorado Plateau	Sierra-Lahontan	
13) Pinus edulis Engelm./ Juniperus osteosperma (Torr.) Little	336	X		Pinyon pine/Utah juniper woodlands from 6000' to 8500' elevation. At lowest levels of this type low sage occurs in the understory along with galleta grass and others. At higher elevations and on deep soils big sage mixes in the type, and at the highest elevational extent Gambel's oak mixes in the type. Analogous to #12.
14) Quercus kelloggii Newb.	343		X	Small stands of California black oak occur in yellow pine forests; also, stands of smaller black oak occur on rocky, burned or variously disturbed hillsides.
15) Quercus gambellii Nutt.	349	X		Dense growth of Gambel's oak occurs on hillsides where Ponderosa pine and Douglas-fir forests used to grow before logging and/or fire. It possesses a highly variable understory with snow-brush (Symphoricarpos), service berry (Amelanchier), green rabbit brush (Chrysothamnus viscidiflorus) being generally present.
16) Pinus jeffreyi Grev. & Balf.	341		X	Jeffrey pine forests occur on slopes and hillsides above the extensive big sagebrush and pinyon-juniper lands. Mixing occurs at both upper and lower ecotones to a variable extent but between 7000'-8000' large forested areas of essentially only this species complex occurs. Analogous to #17.

TABLE I - CONTINUED

Analog Name	Legend Symbol	Presence in Test Sites		Description
		Colorado Plateau	Sierra-Lahontan	
17) Pinus ponderosa Dougl.	341	X		Remnants of once extensive forests occur on level benches and mesas from 7000'-8500' elevation on the Uncompahgre Plateau and high Rocky Mtn. areas of Colorado. The majority of stands possess more or less dense Gambel oak understories.
18) Populus tremuloides Michx.	342	X	X	Extensive areas affected by fire and/or logging are covered by essentially this one overstory species in Colorado. Small stands and pockets of aspen occur in Nevada and California where a water supply is available most of the year. Elevational ranges vary from 6500'-9000' in Nevada to 8000'-10,500' in Colorado.
19) Pinus contorta Dougl. ex Loud.	341	X	X	Lodge pole forests of large size occur both in the mountains of California and Colorado. Generally, these are found at high elevations above 8000'. Where the stands are dense, little understory vegetation other than litter and seedling regeneration is found. The var. murrayana occurs in California while the var. latifolia occurs in Colorado.
20) Pseudotsuga menziesii (Mirb.) Franco	341	X	X	Douglas-fir does not occur in pure stands in either test area. In both sites this species occurs mixed with other conifers including white fir, incense cedar, aspen, spruce and sub-alpine fir.

TABLE I - CONTINUED

Analog Name	Legend Symbol	Presence in Test Sites		Description
		Colorado Plateau	Sierra-Lahontan	
21) *Picea engelmannii* Parry ex Engelm./ *Abies lasiocarpa* (Hook.) Nutt.	341	X		Engelmann spruce/subalpine fir forests occur as the dominant montane/ subalpine vegetation throughout Colorado. No completely analogous type occurs in the Sierra-Lahontan area but #22 may approach this on ERTS imagery.
22) *Abies magnifica* A. Murr./ *Pinus monticola* Dougl./ *Pinus lambertiana* Dougl.	341		X	Red fir forests occur in the montane zone of the Sierra Nevada of California. On north slopes where this type is dense it approaches #21 in appearance visually on ERTS color reconstitutions.
23) *Salix* sp. vegetation	327	X	X	Along mountain streams, in small mountain valleys, and on avalanche tracks in both areas, willow (and alder) communities occur in dense stands.
24) Subalpine meadows	317	X	X	Sedge (*Carex* spp.), grass (*Irisetum*, *Poa*, *Deschampsia*), perennial forb and shrub meadows occur in opening between subalpine forest units and in the alpine zone. Quite often *Veratrum* spp. and *Caltha leptosepala* are important components of this vegetation type.

TABLE I - CONCLUDED

Analog Name	Legend Symbol	Presence in Test Sites		Description
		Colorado Plateau	Sierra-Lahontan	
25) Alpine rocklands	130	X	X	In the alpine zone (10,000' + in California and 11,500' + in Colorado) rock outcrops occur with only scattered perennial alpine, flowering plants, lichens, and mosses making up the vegetation. Composition of bedrock materials will determine signature types to a greater degree than vegetation here, as occurs to some degree in other open vegetation types.

Other vegetation types that have either been located in one test area but not the other or are possible analogous vegetation types but have not been located in either test area include the following:

A. Large stands of native Agropyron

B. Coleogyne ramossisima Torr.--blackbrush

C. Arctostaphylos patula Greene--manzanita

D. Cercocarpus ledifolius/montanus--mountain mahogany

2. Ecological Legend

The Earth surface and land-use legend has been refined to tertiary level categories that are, in most cases, interpretable on ERTS or other small-scale imagery. Narrative of each class down to the tertiary level has been completed and is being evaluated by Earth Satellite personnel in this project and other vegetation projects utilizing ERTS imagery and conventional aerial photography.

A color reconstituted frame of the Colorado Plateau area from 27 September 1972 was interpreted. Secondary level land features were recognizable. In many cases, due to field experience and use of large-scale photographs taken in selected areas, tertiary and more specific floristic levels were often recognizable on the ERTS frame.

Included here is the symbolic and descriptive legend to tertiary levels as it has been slightly modified and further developed since the last Type II report. The only significant change was to add a "cultural vegetation" primary class to provide for permanent, culturally altered vegetations such as planted forests and seeded ranges. Tertiary level detail was added for the 330, Savanna, and the 340, Forest and Woodland types. The quarternary level will reflect broad floristic criteria and is undergoing further development.

Symbolic and Technical Legend Classes

EARTH SURFACE AND LAND-USE FEATURES

PRIMARY CLASSES

100 - BARREN LAND
200 - WATER RESOURCES
300 - NATURAL VEGETATION
400 - CULTURAL VEGETATION
500 - AGRICULTURAL PRODUCTION
600 - URBAN AND EXTRACTIVE INDUSTRY

900 - OBSCURED LAND

SECONDARY CLASSES

100 - BARREN LAND
- 110 - Playas, dry, or intermittent lake basins
- 120 - Aeolian barrens
- 130 - Rocklands
- 140 - Shorelines, beaches, tide flats, and river banks
- 150 - Badlands
- 160 - Slicks
- 170 - Mass movement
- 180 - Man-made barrens
- 190 - Undifferentiated complexes of barren lands

200 - WATER RESOURCES
- 210 - Ponds, lakes, and reservoirs
- 220 - Water courses
- 230 - Springs, seeps, and wells
- 240 - Lagoons and bayous
- 250 - Estuaries
- 260 - Bays and coves
- 270 - Oceans, seas, and gulfs
- 280 - Snow and ice
- 290 - Undifferentiated complexes of water resources

300 - NATURAL VEGETATION
- 310 - Herbaceous types
- 320 - Shrub/scrub types
- 330 - Savanna-like types
- 340 - Forest and woodland types
- 390 - Undifferentiated natural vegetation

400 - CULTURAL VEGETATION
- 410 - Cultural herbaceous types
- 420 - Cultural shrub/scrub types
- 430 - Cultural savanna-like types
- 440 - Cultural forest and woodland types
- 490 - Undifferentiated cultural vegetation types

500 - AGRICULTURAL PRODUCTION
- 510 - Field crops
- 520 - Vegetable and truck crops
- 530 - Tree, shrub, and vine crops
- 540 - Pasture
- 550 - Horticultural specialties
- 560 - Non-producing fallow, transitional, or idle land
- 570 - Agricultural production facilities
- 580 - Aquaculture
- 590 - Undifferentiated agricultural production

600 - URBAN AND RESOURCE EXTRACTION
- 610 - Residential
- 620 - Commercial and services
- 630 - Institutional
- 640 - Industrial
- 650 - Transportation, communications, and utilities
- 660 - Resource extraction
- 670 - Open space
- 690 - Undifferentiated urban

900 - OBSCURED LAND
- 910 - Clouds and fog
- 920 - Smoke and haze
- 930 - Dust and sand storms
- 940 - Smog
- 990 - Undifferentiated obscured land

TERTIARY CLASSES

100 - BARREN LAND

- 110 - Playas, dry or intermittent lake basins
- 120 - Aeolian barrens (other than beaches and beach sand)
  - 121 - Dunes
  - 122 - Sandplains
  - 123 - Blowouts
- 130 - Rocklands
  - 131 - Bedrock outcrops (intrusive & erosion-bared strata)
  - 132 - Extrusive igneous (lava flows, pumice, cinder and ash)
  - 133 - Gravels, stones, cobbles & boulders (usually transported)
  - 134 - Scarps, talus and/or colluvium (system of outcropping strata)
  - 135 - Patterned rockland (nets or stripes)
- 140 - Shore-lines, beaches, tide flats, and river banks
- 150 - Badlands (barren silts and clays, related metamorphic rocks)
- 160 - Slicks (saline, alkali, soil structural, non-playa barrens)
- 170 - Mass movement
- 180 - Man-made, land fill
- 190 - Undifferentiated complexes of barren lands

200 - WATER RESOURCES

210 - Ponds, lakes, and reservoirs
211 - Natural lakes and ponds
212 - Man-made reservoirs and ponds

220 - Water courses
221 - Natural water courses
222 - Man-made water courses

230-270, and 290 - No tertiary classes to date.

280 - Snow and ice
281 - Seasonal snow cover
282 - Permanent snow fields and glaciers

300 - NATURAL VEGETATION

310 - Herbaceous types
311 - Lichen, cryptogam, and related communities
312 - Prominently annuals
313 - Forb types
314 - Grassland, steppe, and prairie
315 - Meadows
316 - Graminaceous marshes
317 - Tule marshes
318 - Bogs
319 - Undifferentiated complexes of herbaceous types

320 - Shrub/scrub types
321 - Microphyllous, non-thorny scrub
322 - Microphyllous thorn scrub
323 - Succulent and cactus scrub
324 - Halophytic shrub
325 - Shrub steppe
326 - Sclerophyllous shrub
327 - Macrophyllous shrub
328 - Microphyllous dwarf shrub
329 - Undifferentiated complexes of shrub/scrub types

330 - Savanna-like types
331 - Tall shrub/scrub over herb layer
332 - Broad-leaved tree over herb layer
333 - Coniferous tree over herb layer
334 - Mixed tree over herb layer
335 - Broad-leaved tree over low shrub layer
336 - Coniferous tree over low shrub layer
337 - Mixed tree over low shrub layer
339 - Undifferentiated complexes of savanna-like types

340 - Forest and woodland types
341 - Conifer forests
342 - Broadleaf forests
343 - Conifer-broadleaf mixed forests and woodlands
349 - Undifferentiated complexes of forest and woodland types

390 - Undifferentiated natural vegetation - No tertiary classes to date.

400 - CULTURAL VEGETATION

410 - Cultural herbaceous types
411-419 - Tertiary levels duplicate those of NATURAL VEGETATION (300)

420 - Cultural shrub/scrub types
421-429 - Tertiary levels duplicate those of NATURAL VEGETATION (300)

430 - Cultural savanna-like types
431-437, 439 - Tertiary levels duplicate those of NATURAL VEGETATION

440 - Cultural forest and woodland types
441-443, 449 - Tertiary levels duplicate those of NATURAL VEGETATION

490 - Undifferentiated cultural vegetation types - No tertiary classes to date.

500 - AGRICULTURAL PRODUCTION

510 - Field crops
511 - Cereal and grain crops
512 - Forage crops
513 - Sugar crops
514 - Drug, flavoring, and spice crops
515 - Oil crops
516 - Rubber crops
517 - Fiber crops
519 - Undifferentiated field crops

520 - Vegetable and truck crops
521 - Legume crops
522 - Salad, green, and cole crops
523 - Cucurbit crops
524 - Solanaceous crops
525 - Root, tuber, and bulb crops
526 - Perennial vegetable and fruit crops
529 - Undifferentiated vegetable and truck crops

530 - Tree, shrub, and vine crops
531 - Shrub, vine, and bramble fruits
532 - Deciduous tree fruits
533 - Citrus tree fruits
534 - Evergreen tree fruit crops
535 - Deciduous nut crops
536 - Evergreen nut crops
537 - Beverage crops
539 - Undifferentiated tree, shrub, and vine crops

540 - Pasture
541 - Herbaceous pasture
542 - Shrubby pasture

550 - Horticultural specialties
- 551 - Flower stock
- 552 - Shrubbery stock
- 553 - Tree stock
- 554 - Mixed stocks
- 559 - Undifferentiated horticultural stocks

560 - Non-producing fallow, transitional, or idle land
- 561 - Fallow cropland
- 562 - Plowed cropland
- 563 - Leached cropland
- 564 - Harvested stubble fields
- 565 - Entrapped, idle, or abandoned land

570 - Agricultural production facilities
- 571 - Meat production
- 572 - Dairy production
- 573 - Fowl production
- 574 - Small animal production
- 575 - Specialty animal production
- 576 - Plant production

580 - Aquaculture
- 581 - Hatcheries
- 582 - Shellfish beds

590 - Undifferentiated agricultural production - No tertiary classes to date.

600 - URBAN AND RESOURCE EXTRACTION

610 - Residential
- 611 - Tract homes
- 612 - Tenement and apartment homes
- 613 - Planned unit developments
- 614 - Mobile homes
- 615 - Mixed housing
- 619 - Undifferentiated residential

620 - Commercial and services
- 621 - Wholesale trade facilities (Foodstuffs, dry goods, etc. with indoor storage)
- 622 - Wholesale trade facilities (Hardware, machinery, etc. with outdoor storage)
- 623 - Retail trade facilities (Foodstuffs, dry goods, etc. with indoor storage)
- 624 - Retail trade facilities (Hardware, machinery, etc. wtih outdoor storage)
- 625 - Personal, professional, repair, and recreational service facilities
- 626 - Cultural services
- 629 - Undifferentiated commercial and services

630 - Institutional
- 631 - Public and private educational facilities (including religious schools with no connection to a major chapel)
- 632 - Religious facilities (including religious schools associated with a major chapel)
- 633 - Health facilities
- 634 - Governmental institutions
- 635 - Military facilities and reservations
- 636 - Conventional cemeteries
- 639 - Undifferentiated institutional facilities

640 - Industrial
- 641 - Light industries and assembly industries
- 642 - Heavy industries

650 - Transportation, communications, and utilities (and their rights-of-way)
- 651 - Rail transit facilities
- 652 - Motor vehicle transport facilities
- 653 - Marine transport facilities
- 654 - Air transport facilities
- 655 - Communications facilities
- 656 - Power production facilities
- 657 - Utilities (distribution and transmission)
- 658 - Sewer and solid waste facilities
- 659 - Undifferentiated transportation, communications, and utilities

660 - Resource extraction
- 661 - Sand and gravel
- 662 - Rock quarries
- 663 - Petroleum, gas, and related
- 664 - Coal, peat, and related
- 665 - Chemical, fertilizer, and non-metalic minerals
- 666 - Metals
- 669 - Undifferentiated extraction resources

670 - Open space and recreational facilities
- 671 - Designated natural open space
- 672 - Recreational open space
- 673 - Recreational facilities
- 674 - Memorial parks
- 675 - Buffer open space
- 679 - Undifferentiated open space

690 - Undifferentiated urban - No tertiary classes to date.

MACRORELIEF

1.0 - Flat lands (Prominent slopes $<10\%$)
- 1.1 - Non-dissected
- 1.2 - Dissected

2.0 - Moderately undulating to rolling lands (Slopes 10 - 25%)

2.1 - Non-dissected
2.2 - Dissected

3.0 - Hilly lands (Slopes < 25%, <1,000' relief, smooth slopes, simple drainage systems)

4.0 - Mountainous lands (Slopes, relief, and complexity greater than in 3.0)

LANDFORM FEATURES

1.0 - Depressional or wet lands, non-riparian

1.1 - Intertidal zone
1.2 - Swamps and marshes
1.3 - Seasonally ponded basin

2.0 - Bottomlands, riparian

2.1 - Stringer or narrow bottomlands
2.2 - Wide valley bottoms, substantial flood plains
2.3 - Seasonal streambeds and washes

3.0 - Planar surfaces

3.1 - Fans and bajadas
3.2 - Terraces
3.3 - Gently undulating to rolling uplands, plateaus, table-lands and mesas
3.4 - Pediments

4.0 - Aeolian featured landscapes

5.0 - Slope Systems (Slope classes according to the following table, class is the one-hundredths 0.0X digit).

Slope Range %	Slope Class Digit
Simple Slope Systems	
0 - 5	.01
5+ - 15	.02
15+ - 30	.03
30+ - 50	.04
50+ -100	.05
<100	.06

Slope Range %	Slope Class Digit
Complex Slope Systems	
0 - 30	.07
0 - 50	.08
0 - 100+	.09
15 - 50	.09

The 0.X digit in each case is reserved for landform feature subclass. The slope classes may be added to any appropriate landform feature class by the notation 0.0X, e.g., 4.03; 6.08; 3.22.

Descriptive Legend for Selected Classes

Primary Classes

100 - BARREN LAND: Barren land is somewhat relative but it is intended to cover all situations where the earth surface is essentially barren, rock, gravel, or mineral soil. It is impossible to specify a vegetational cover percentage threshold for barren land. For example, a talus slope with a few shrubs around the periphery or rarely within the talus would still be a barren land class. Desert vegetation will cause the most problem. If the natural ecosystem in a desert climate is sparsely vegetated, it would fall into one of the desert classes, usually symbol 320, even though total percentage ground cover may be well under 10 percent. The more common barren land classes in the desert scene are desert pavement or gravel cover falling into class 133, playas class 110, badlands 150, or slicks 160. Barren lands in desert environments should be almost completely devoid of any vegetation. Commonly in the desert uplands there are scarps, talus, and colluvia, class 134. To the casual observer, many of these will appear essentially barren but if they support a scattered vegetation uniformly throughout the area of steep desert slopes, they should carry an appropriate 300 class.

200 - WATER RESOURCES: Include all ground surface areas covered by natural or man-made water surfaces--streams, lakes, reservoirs, snow and ice, canals, enclosed aqueducts, and other water bodies lacking a surface vegetational cover. This class includes lakes and ponds with heavy "algal bloom" but not ponds with a floating or moderately dense, emergent vegetational covering.

300 - NATURAL VEGETATION: This class includes natural or native vegetation consisting of essentially indigenous species or introduced species that have become essentially naturalized to the region and that have found an ecological niche as though they were a part of the original vegetation. This class includes all successional stages in the natural vegetation. In mapping and identification, one should avoid trying to map the presumed "climax" or eventual equillibrium vegetation. Map and identify vegetation as it exists at the time imagery was obtained. The postulation of climax areas comes later as an interpretation of the basic inventory.

400 - CULTURAL VEGETATION: This class provides for the culturally introduced and intensively managed vegetations where the management objective is essentially maintenance of a permanent stand subsequently managed and manipulated through ecological rather than agronomic principles. The class is designed primarily to provide for seeded range where the intention is permanency of stand and the planted forest, e.g., grass seedings in a shrub steppe land or savanna land and planted coniferous forests in a hardwood forest area.

Some would argue this class should be in primary category 500, agricultural production. We prefer the class 400 because, generally, foresters and range managers prefer to identify these intensively treated areas as forests and rangeland respectively.

Removal of woody overstory species on potential rangeland, range seedings and clear-cut forests allowed to revert to natural successional patterns are classed in the appropriate 300 category. These types are treated as seral vegetation. If, however, such areas were additionally planted to exotic species not initially natural to the site, they would then be classed under the appropriate 400, cultural vegetation, category.

500 - AGRICULTURAL PRODUCTION: These are land areas cleared of the natural vegetation and managed by agronomic principles for production of food, fiber or fodder crops. The class includes any land areas or structures and facilities directly related to intensive agricultural practices. These agricultural lands are characterized by the relatively constant manipulation by man through control of the vegetation and micro-environment (fertilization, irrigation, etc.).

This class includes the permanent pasture managed for maximum yield by fertilization, irrigation and periodic renovation. These are pastures generally included within or in juxtaposition with the crop field boundary also meeting the above criteria.

Forests or woodland windbreaks and woodlocks included within the cropland area would be treated by the appropriate 300 or 400 subclass if the units are of mappable size.

600 - URBAN AND RESOURCE EXTRACTION: Without a long title, semantics leads to misunderstanding about this class. It includes all urban, industrial, and resource extraction activities that have modified the natural landscape. The class also includes lands allocated to open space but where man has modified the environment through agronomic, horticultural, or landscaping activities.

Natural areas of mappable size located within urban areas would be treated under the appropriate 300 class. If they were planted forests or woodlands used as open space or for screening with the urban-industrial environment, they would be treated as appropriate 400, cultural vegetational subclasses.

900 - OBSCURED LAND: This class is intended to provide for those portions of remotely sensed imagery in which the earth's surface is essentially obscured by clouds and other atmospheric obstruction. It is used primarily where it becomes necessary to account for 100% of the image frame area.

Secondary Classes

100 - BARREN LAND: Experience has shown that barren land subclasses should never go beyond tertiary level and frequently it is unnecessary to go beyond the secondary class. To do so makes the barren land class redundant with geological information where the latter is assessed as a component of the physical environment or land surface.

Practically all of the secondary classes under 100 are self-explanatory. Problems most frequently arise with class 150 badlands and class 180 man-made barrens or land fills. Badlands are generally best identified by their intricate drainage patterns and usually irregular slopes and relief although many present a smoothly sloping relief. This class is intended to provide primarily for those barren lands derived from silty and clayey materials or from relatively easily weathered rocks that may produce an intricately grotesque or spire-like series of relief features.

Class 180 should be restricted to man-made land fill and not confused with extractive industry classes that typically generate barren lands, e.g., open pits mining, which fall under class 660, an industrial category.

200 - WATER RESOURCES: These secondary subclasses are all self-explanatory or defined in standard dictionaries. The main divergence of this legend system from others in use is the inclusion of snow and ice, 280, as a sub-category. This seems far more logical to us than separating snow and ice at primary levels as is sometimes done. By inclusion as a subset it permits easy agglomeration of all water resource features in a study area or watershed.

300 - NATURAL VEGETATION:

310 - HERBACEOUS TYPES: That vegetation (annual, biennial, or perennial) which in aspect is dominantly herbaceous--including any or all grasses, grass-like plants, forbs, and non-vascular or vascular cryptogams. Other growth forms of vegetation may be present but they are decidedly subordinate in terms of aspect.

320 - SHRUB/SCRUB TYPES: All types of shrubs are the prominent vegetation. These usually form a closed or nearly closed layer so that the herbaceous layer is subordinate. The herbaceous ground layer of this vegetation is highly variable but can be important. The aspect is one of a prominently low woody vegetation.

330 - SAVANNA-LIKE TYPES: The world literature in no way agrees on the definition of a savanna. We have thus been somewhat arbitrary in phrasing the following descriptive definition that seems to fit most temperate and many tropical situations where the expression savanna has been used to describe the unique community. In contrast to some tropical writers, we are not including the tall grass, sparse overstory with a dense shorter grass understory as savanna. This latter belongs in the 310, herbaceous class. Vegetation consisting of sparse, taller woody plants interspersed somewhat regularly throughout

by a more dense low shrub or herbaceous layer to give a distinct two-storied community.

We have tested many percentage cover thresholds in the tall woody layer to differentiate or characterize the savanna. Most of these have been difficult to apply consistently because of variation in the size of the individuals in the tall layer. The larger the size, the more widely they can be dispersed and still present an accurate savanna-like aspect. We therefore prefer not to specify such thresholds but to say that the vegetations should be savanna-like in their appearance or aspect to match as closely as possible the intent of the above description.

340 - FOREST and WOODLAND TYPES: The tree layer forms the dominant vegetational feature. This layer often forms a closed canopy over a variety of subordinate vegetation types.

400 - CULTURAL VEGETATION: The secondary classes for cultural vegetation are the same as those presented above for class 300.

500 - AGRICULTURAL PRODUCTION:

510 - FIELD CROPS: Cereals, grains, forage, drugs, spices, fiber crops and other field crops which are the dominant land use.

520 - VEGETABLE and TRUCK CROPS: Legumes, leafy vegetables, roots, tubers, bulbs, cucurbit, solanaceous, and perennial vegetable crops (including other herbaceous crops such as fruit crops) are in this category.

530 - TREE, SHRUB, and VINE CROPS: Fruit, nut, and beverage crops with tree, shrub, or vine growth forms.

540 - PASTURE: Any intensively managed land (fertilized, irrigated and/or renovated or appropriate) utilized for grazing or browsing, with or without periodic mechanical harvest. A pasture may be harvested as a "permanent" crop or managed as a temporary lay in a crop rotation plan.

550 - HORTICULTURAL SPECIALTIES: Artificially planted and maintained flower, shrub, or tree stock. This includes nursery stock, flowers (whether grown for seed, rootstocks, corns, bulbs, tubers, or blooms), and other herbaceous horticultural plants occurring in various sized production lots.

560 - NON-PRODUCING FALLOW, TRANSITION, or ENTRAPPED LAND: Fallow plowed (or variously worked), and leached cropland including harvested fields; included here are abandoned or idle croplands, fields, and pastures as well as entrapped lands that are isolated from effective agricultural production by being surrounded or blocked from access by class 600 lands.

570 - AGRICULTURAL PRODUCTION FACILITIES: At all but the largest of inventory scales, these features usually represent point data, i.e., of non-mappable size but they may be particularly important to annotate, especially in complete land-use inventories. Structures and facilities utilized for animal or plant production (except fisheries, see class 580) make up this category. Barns, sheds, holding pens, and greenhouses are examples.

580 - AQUACULTURE: Fish and shellfish hatcheries or other structures, rearing areas, and production ponds are included in this category.

600 - URBAN:

610 - RESIDENTIAL: Single and multiple unit dwellings including secondary structures, driveways, and landscaped areas. Sparse residential land-use should be treated as point data within that land-use or resource class within which they are dispersed.

620 - COMMERCIAL and SERVICES: Areas used predominantly for the sale, storage, and handling of products and services. Suburban and city shopping centers, warehouses, waste-disposal areas, office buildings, parking lots, and intensively developed resort sites are examples of this category.

630 - INSTITUTIONAL: Education, religious, health, correctional, and military facilities are the main components of this category. All buildings, grounds, and lots that make up the facility are included here. Areas not specifically related to the prupose of the institution should be placed in the appropriate category.

640 - ACTIVITY CENTERS, and AREAS: Centers of human cultural, artistic, and recreational activities where structures compose the majority of the facility (as opposed to open or landscaped space, see class 680). Land areas may be variously developed by landscaping techniques but the aerial extent of the landscaped land is less than the structures utilized in the activity. Opera houses, stadiums, civic centers, theaters, and other activity centers are examples of this category.

650 - INDUSTRIAL: All types of light manufacturing and industrial parks to heavy manufacturing. Light industries concentrate on finishing, assembling, designing, and packaging products while heavy industries require more or less large amounts of raw materials such as

metal ores, timber, and other materials. These heavy industry sites are usually associated with concentrations of raw materials, transportation facilities, power sources, and waste products.

660 - TRANSPORTATION, COMMUNICATIONS, AND UTILITIES: Highways and railways make up the two basic transportation means that require stationery routings visible on remote sensing images. Facilities related to all transportation types are included in this category (seaports, airports, runways, railroad terminals, bus terminals, highways, roads, etc.). Resource transportation facilities that are non-mobile themselves are included in this category (oil pipelines, gas, electricity and airwave facilities).

670 - RESOURCE EXTRACTION: Surface and subsurface mining facilities are included in this category. Areas of reserves and future operations are included in other land-use or resource categories. Where resource areas cease to be in a raw extractive state the activities and structures are classed in the Industrial category. Gravel, earth, clay, oil, coal, metals, and gas are examples of resource types.

680 - OPEN SPACE: Land areas in intensive or low intensity use may be included in this category. Activities and facilities requiring significant land area that is the dominant or the major prerequisite to the activity itself are included in this category. Parks, ski areas, golf courses, cemeteries and other open lands are included in this category. The open space far exceeds the proportion of area occupied by structures required for related activities.

900 - OBSCURED LAND:

910 - CLOUDS AND FOG: Naturally occurring water vapor obscuring the land surface.

920 - SMOKE AND HAZE: Natural or man-caused smoke or haze dense enough to obscure the land surface.

930 - DUST AND SAND STORMS: Sand, silt and/or clay particles born aloft and dense enough to obscure the land surface.

940 - SMOG: Man-caused particulate matter, vapors, chemicals and other smog substances suspended in the atmosphere densely enough to obscure the land surface.

Tertiary Classes

310 - HERBACEOUS TYPES:

311 - LICHEN, CRYPTOGAM, and RELATED COMMUNITIES: Areas with lichens, masses, liverworts, algae, fungi, vascular cryptogams and any other non-woody non-angiospermous plants occurring as the dominant vegetation. This class is primarily used in arctic and alpine tundra conditions. Lichen covered rocklands should be classed 130, not 310.

312 - PROMINENTLY ANNUALS: Areas often devoid of vegetation during much of the year with more or less dense annual plants growing during certain seasons of favorable precipitation. This class usually possesses a gramineous aspect.

313 - FORB TYPES: Biennial or perennial broadleaved herbs forming the dominant vegetation. This class does not include prominence of grasses, grass-like plants, and vascular cryptogams.

314 - GRASSLAND, STEPPE, and PRAIRIE: Any land area dominated by grass vegetation. Tall grass prairies, short grass prairies, desert grasslands, "midgrass plains", bunchgrass, and grass dominant steppes are all included in this category.

315 - MEADOWS: Areas dominated generally by species of Gramineae (grasses) or Cyperaceae (and related families, sedges and rushes, grass-like) where soil moisture conditions fluctuate greatly from one season to the next but tend toward mesism.

316 - GRAMINACEOUS MARSHES: Hygric (very wet) vegetation dominated by mixtures or dense stands of individual grass species.

317 - TULE MARSHES: Hygric (very wet) vegetation dominated by Juncaceae (rushes), Cyperaceae (sedges), Typhaceae (cattails), or other aquatic and sub-aquatic angiosperms (seed plants).

318 - BOGS: Hygric vegetation dominated by Sphagnum and/or other mosses, cryptogamic or bog inhabiting plants.

320 - SHRUB/SCRUB TYPES:

321 - MICROPHYLLOUS, NON-THORNY SHRUB/SCRUB: Small-leaved, non-thorny, small shrub or scrub species occurring as the dominant overstory vegetation type. Microphyllous desert shrublands are the dominant areas with these vegetation types.

322 - MICROPHYLLOUS THORN SHRUB/SCRUB: Small-leaved, thorny shrub or scrub species occurring as the dominant overstory vegetation. This category includes desert thorn scrub predominantly.

323 - SUCCULENT and CACTUS SCRUB: Cactaceae (cactus), Euphorbiaceae (cactus-like), and other succulent plants occurring as the dominant vegetation type.

324 - HALOPHYTIC SHRUB: Salt tolerant shrubs occurring as dominant vegetation type predominantly in playas, alkali flats and other soils with high salt contents. This class includes such genera as Atriplex, Eurotia, Gravia, and Sarcobatus.

325 - SHRUB STEPPE: Artemisia, Chrysothamnus, Purshia, Cowania and other shrubs occurring as the dominant vegetation over a subdominant or co-dominant stand of grasses (including some forbs) in the understory.

326 - SCLEROPHYLLOUS SHRUB: Shrublands with leathery-leaved, evergreen species adapted to xeric and mediterranean environments occurring as the dominant vegetation. This category includes chaparral (Quercus, Arctostaphylos, Ceanothus, Cercocarpus) and chamise types (Adenostoma-Salvia).

327 - MACROPHYLLOUS SHRUB: Large-leaved, deciduous shrubs occurring as the dominant vegetation; including Salicales (willows), Rosales (rose), Aceraceae (maple), Shepherdia, Symphoricarpos (snowbush), and some Ericales (heaths).

328 - MICROPHYLLOUS DWARF SHRUB: Small-leaved shrubs forming the dominant vegetation type; including ericaceous arctic and alpine heath vegetation and shrub bogs. This is predominantly an arctic-alpine class.

330 - SAVANNA-LIKE TYPES:

331 - TALL SHRUB/SCRUB OVER HERB LAYER: Tall shrubs and scrubby tree species occurring over a predominantly herbaceous layer that is co-dominant with or more prominent than the shrub/scrub vegetation.

332 - BROAD-LEAVED TREE OVER HERB LAYER: Evergreen, semi-deciduous, or deciduous angiosperm tree species over herbaceous vegetation.

333 - CONIFEROUS TREE OVER HERB LAYER: Coniferous tree species over herbaceous vegetation.

334 - MIXED TREE OVER HERB LAYER: Coniferous and angiospermous tree species over an herbaceous layer, with either predominating but neither tree type $<20\%$ cover.

335 - BROAD-LEAVED TREE OVER LOW SHRUB: Evergreen, semi-deciduous, or deciduous angiospermous tree species over low shrub layer.

336 - CONIFEROUS TREE OVER LOW SHRUB: Coniferous tree species over a low shrub layer.

337 - MIXED TREE OVER LOW SHRUB: Coniferous and angiospermous tree species over a low shrub layer, with either predominating but neither tree type $<20\%$ cover.

340 - FOREST and WOODLAND TYPES:

341 - CONIFER FORESTS: Forested areas of cone-bearing trees dominated by any Coniferales or Taxales.

342 - BROADLEAF FORESTS: Deciduous, semi-deciduous, or evergreen angiospermous (flowering) forest species.

343 - CONIFER-BRAODLEAF MIXED FOREST and WOODLAND: Any conifers and Taxales and broadleaf angiosperms mixed in a dense forest growth or more open woodlands. Cover of the conifer-broadleaf mixture may vary from 20-80% to 80-20%, respectively.

3. Digital Data Analysis of Sierra-Lahontan Vegetation Types:

An area north of Honey Lake and the west shore of Honey Lake was analyzed from ERTS digital data. Gray scale printouts were utilized to outline training sets in both areas. A vegetation classification was done in cooperation with Robin Mowlem of IBM in Gaithersburg, Maryland.

On the north shore six classes were distinguished as indicated in Figure 1.

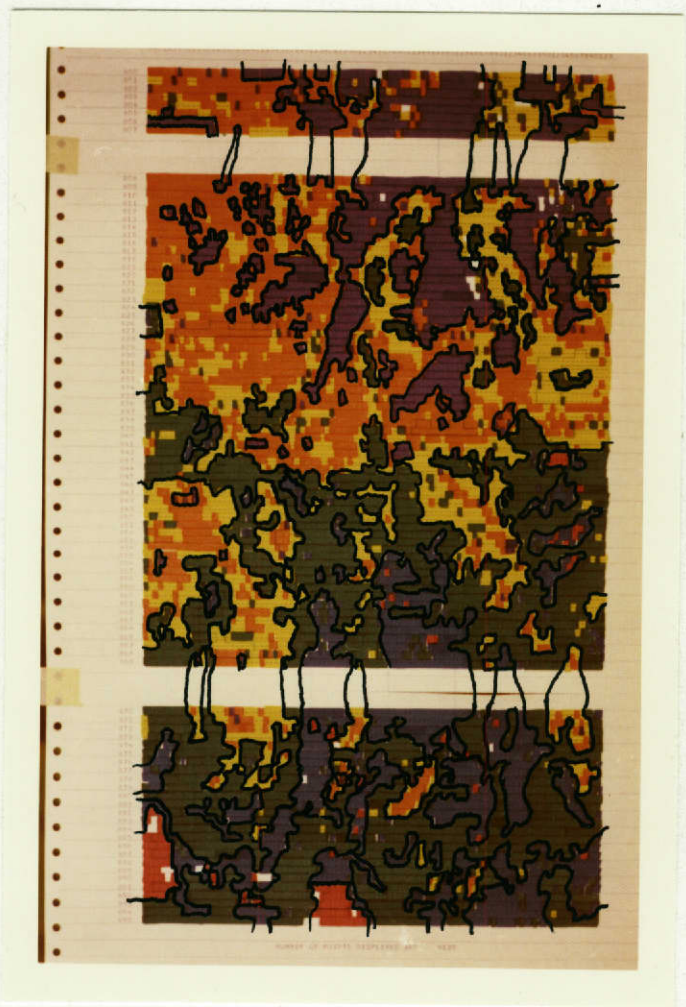

Figure 1. CLASSIFICATION: NORTH SHORE, HONEY LAKE, CALIFORNIA. ERTS-1003-18170, 26 July 1972.

Red areas (see Figure 1) on the color coded printout indicate agricultural fields. Green areas are dominated by big sagebrush (Artemisia tridentata) with Bromus tectorum occurring abundantly in the understory. Soils are moderately deep and sandy thus entering into the image as a significant feature during the dry season when little annual brome is covering the ground surface.

Blue areas indicate mixed big sagebrush and bitterbrush (Purshia tridentata) on slopes and rocky ridges above the moderate slopes supporting pure big sagebrush. Bitterbrush is an important browse species.

A marked break in slope and change in species composition appears to be indicated by yellow and orange areas. These areas are moderate-to-steep slopes with high percentages of open, rocky ground. Vegetation types appear to be essentially similar on yellow and orange areas. Artemisia tridentata ssp. xericensis, a low-statured variety of big sagebrush, is dominant on these areas with large amounts of Sandberg's bluegrass, and needlegrass along with other semi-desert annual species.

Purple areas include extensive areas dominated by Agropyron spicatum, an important perennial bunchgrass. These areas are readily identifiable visually on ERTS imagery while the other types are much more difficult to distinguish visually.

In the test area north of Honey Lake we were encouragingly surprised at the degree to which individual vegetation soil systems were classifiable. Even though this classification was not perfect, it clearly shows the potential for extracting information appropriate to moderately intensive management from the ERTS data.

In Figure 2 the means and one standard deviation have been expressed graphically for the multispectral signature of each test set. The classes illustrated refer to individual colors on the actual classification attempt, Figure 1. Class A represents the signature for water taken from the same tape just south of this test area on the north shore of Honey Lake. Class B refers to the red areas in Figure 1. Class C refers to the blue areas; Class D refers to the green areas; Class E refers to the orange areas; Class F refers to the yellow areas; and Class G refers to the purple areas.

Table II demonstrates the success with which individual picture cells included in the training classes were classified into the correct vegetation types.

A classification was also attempted on the west shore of Honey Lake. This area presented more subtle and intricate vegetational variation. It is covered by coniferous forests, small areas of shrublands, some rock outcrops and agricultural fields. Training set selection was extremely difficult without the aid of larger scale photography. The training sets turned out to be quite heterogeneous mixtures of vegetation types, plant density patterns, rock outcropping and other variables. Thus the first classification attempt in this area did not reflect vegetative community patterns to a very high degree. The problem is not, however, with the system but rather with the extreme difficulty of designating pure training sets from the multiband computer printouts. This problem can be solved by use of support photography.

On both sites improved training areas will be selected and another classification of vegetation types attempted.

LARSYS/M LABORATORY FOR APPLICATIONS OF REMOTE SENSING DATE JULY 1972
VERSION 2 PURDUE UNIVERSITY

HONEY LAKE CLASSIFICATION

COINCIDENT SPECTRAL PLOT (MEAN PLUS AND MINUS ONE STD. DEV.) FOR CLASS(ES)

LEGEND
A = CLASS 1 WATER
B = CLASS 2 C1
C = CLASS 3 C2
D = CLASS 4 C3
E = CLASS 5 C4
F = CLASS 6 C5
G = CLASS 7 C6

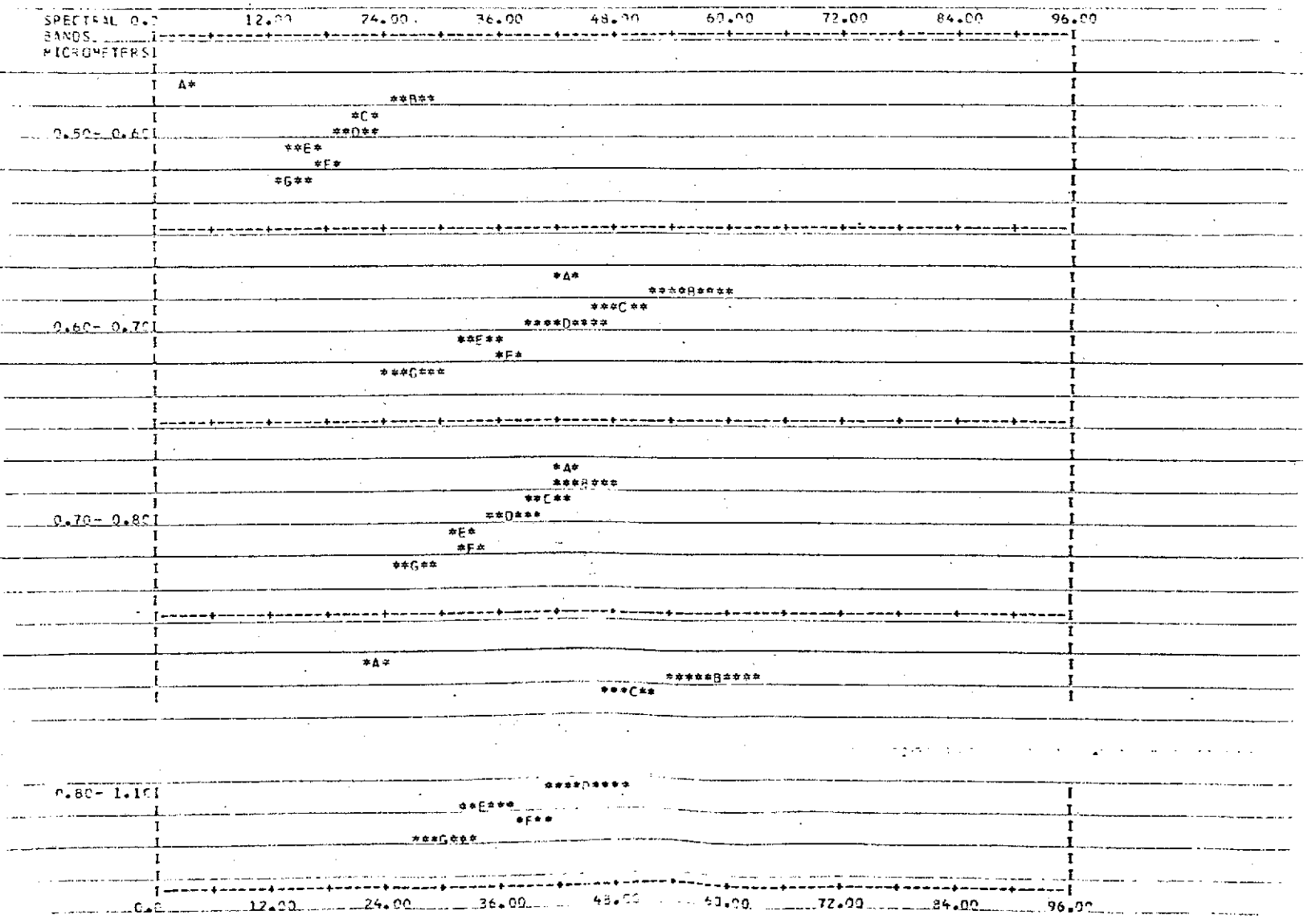

Figure 2. MEANS AND STANDARD DEVIATIONS OF MULTISPECTRAL SIGNATURES OF NATURAL VEGETATION TEST SETS, NORTH SHORE, HONEY LAKE, CALIFORNIA

Table II

TRAINING CLASS PERFORMANCE

CLASSES

	CLASS	THRES PCT		CLASS	THRES PCT
1	WATER	5.0	5	C4	5.0
2	C1	5.0	6	C5	5.0
3	C2	5.0	7	C6	5.0
4	C3	5.0			

TRAINING CLASS PERFORMANCE

	CLASS	NO OF SAMPS	PCT. CORCT	NUMBER OF SAMPLES CLASSIFIED INTO: WATER	C1	C2	C3	C4	C5	C6	THRSHOLD
2	C1	54	90.7	0	49	5	0	0	0	0	0
3	C2	192	86.5	0	6	166	20	0	0	0	0
4	C3	62	79.0	0	5	7	49	0	1	0	0
5	C4	68	86.8	0	0	0	0	59	8	1	0
6	C5	69	94.2	0	0	0	1	3	65	0	0
7	C6	167	95.2	0	0	0	1	6	1	159	0
	TOTAL	612		0	60	178	71	68	75	160	0

WORK SCHEDULE

Imagery has been received on a more acceptable schedule although color products are still being delayed for extended periods. Our work schedule is within tolerance as shown on our Data Analysis Plan and we anticipate remaining on schedule.

PROBLEMS

Image quality problems have been resolved and our investigation progresses with no other major problems.

FUNDING

No change--costs are being controlled within the allotted budget.

PERSONNEL

Mr. Dennis Jaques began working on the project under Poulton's guidance while completing his Master's Degree in plant taxonomy and ecology at Oregon State University. He joined EarthSat full time in July. Mr. Jaques is now primary support scientist on the Natural Vegetation Analog study. No other changes in personnel have been made.

PLANS FOR NEXT REPORTING PERIOD

Rice Analog Studies

Intensive image interpretation of both ERTS and aircraft data will continue in order to monitor the status and quality of the rice crops in California and Louisiana. We anticipate receiving high-quality ERTS coverage from the June 29, 1973 Louisiana overpass which came at a most

opportune time. Our flight crew was taking aerial photos at the same time ERTS was passing over and we will be able to make excellent image evaluations if all systems functioned properly.

We plan similar comparisons in the California area as we have excellent aerial photos that correspond with ERTS overpasses.

Image interpretation will be used to establish the usefulness of ERTS photos for crop identification and evaluation of crop condition based on ground truth obtained by a combination of aircraft photos and ground visits.

Natural Vegetation Analog Studies

Using both NASA highflight and large-scale aerial photography taken by EarthSat, a multistage analysis of color reconstituted ERTS imagery will be conducted to determine the success with which vegetation types and analogs can be identified in the same frame area. Once color products we have ordered arrive, the same procedure will be attempted on different frames in the same region and also between the two inter-regional test areas.

Color enlargements of selected ERTS frames will also be produced on our own Addcol, optical color combiner. With this material, an omission-commission test will be conducted to determine the extent to which analogous vegetation types can be identified by visual means both inter-regionally and intra-regionally.

Once color products from NASA are made available, an attempt will be made to quantify the image characteristics of selected vegetation types and analogs. Again this will be done inter-regionally and intra-regionally.

The color products have been ordered on a multi-date basis so that important phenological changes can be monitored. Phenological data obtained from ERTS imagery will be correlated with information obtained from field personnel in each area who have agreed to collaborate on the project.